Fluoroscopy-guided versus CT-guided Lumbar Steroid Injections: Comparison of Radiation Exposure and Outcomes

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Abstract: Purpose To compare the radiation exposure for participants and interventionalists as well as participant outcomes between fluoroscopy-guided versus CT-guided lumbar spinal injections. Materials and Methods This prospective, nonrandomized observational study included 1446 participants (mean age, 60.6 years; range, 18-91 years) who received transforaminal epidural injections or facet joint injections under fluoroscopic or CT guidance between October 2009 and April 2016. Effective doses were estimated by conversion from dose-area product for fluoroscopy-guided injections and dose-length product for CT-guided injections. Radiation exposure for interventionalists was measured with dosimeters at the body and wrist. The Patient Global Impression of Change (PGIC) scale was used to assess clinical participant outcomes at 1 day, 1 week, and 1 month after lumbar spine injections. Student t and tests were used for statistical analysis. Results The mean effective participant dose for fluoroscopy-guided lumbar transforaminal epidural injections was 0.24 mSv ± 0.22, compared with 0.33 mSv ± 0.10 for CT-guided injections ($P < .003$). The mean effective participant dose for fluoroscopy-guided lumbar facet joint injections was 0.10 mSv ± 0.11, compared with 0.33 mSv ± 0.13 for CT-guided injections ($P < .001$). Radiation exposure for the interventionalist was higher during fluoroscopy-guided compared with CT-guided lumbar transforaminal epidural injections (body: 0.42 × 10 mSv ± 0.99 vs 0.11 × 10 mSv ± 0.44, $P < .03$; wrist: 1.44 × 10 mSv ± 2.69 vs 0.14 × 10 mSv ± 0.55, $P < .001$). Radiation exposure of the wrist for the interventionalist was higher during fluoroscopy-guided compared with CT-guided lumbar facet injections (0.46 × 10 mSv ± 0.93 vs 0.06 × 10 mSv ± 0.24, respectively; $P < .006$). Clinical participant outcomes as determined with the PGIC scale did not differ between fluoroscopy-guided and CT-guided injections ($P = .15$-.96). Conclusion Radiation exposure in fluoroscopy-guided lumbar spinal injections was lower for participants and higher for physicians when compared with CT-guided injections; however, no associations were observed between clinical participant outcomes and type of imaging-guided injection technique at all evaluated time points.

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Radiology

Fluoroscopy-guided versus CT-guided Lumbar Steroid Injections: Comparison of Radiation Exposure and Outcomes

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Conflicts of interest are listed at the end of this article.

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Purpose: To compare the radiation exposure for participants and interventionalists as well as participant outcomes between fluoroscopy-guided versus CT-guided lumbar spinal injections.

Materials and Methods: This prospective, nonrandomized observational study included 1446 participants (mean age, 60.6 years; range, 18–91 years) who received transforaminal epidural injections or facet joint injections under fluoroscopic or CT guidance between October 2009 and April 2016. Effective doses were estimated by conversion from dose-area product for fluoroscopy-guided injections and dose-length product for CT-guided injections. Radiation exposure for interventionalists was measured with dosimeters at the body and wrist. The Patient Global Impression of Change (PGIC) scale was used to assess clinical participant outcomes at 1 day, 1 week, and 1 month after lumbar spine injections. Student *t* and χ^2 tests were used for statistical analysis.

Results: The mean effective participant dose for fluoroscopy-guided lumbar transforaminal epidural injections was 0.24 mSv ± 0.22, compared with 0.33 mSv ± 0.10 for CT-guided injections ($P < .003$). The mean effective participant dose for fluoroscopy-guided lumbar facet joint injections was 0.10 mSv ± 0.11, compared with 0.33 mSv ± 0.13 for CT-guided injections ($P < .001$). Radiation exposure for the interventionalist was higher during fluoroscopy-guided compared with CT-guided lumbar transforaminal epidural injections (body: 0.42×10^{-3} mSv ± 0.99 vs 0.11×10^{-3} mSv ± 0.44, $P < .03$; wrist: 1.44×10^{-3} mSv ± 2.69 vs 0.14×10^{-3} mSv ± 0.55, $P < .001$). Radiation exposure of the wrist for the interventionalist was higher during fluoroscopy-guided compared with CT-guided lumbar facet injections (0.46×10^{-3} mSv ± 0.93 vs 0.06×10^{-3} mSv ± 0.24, respectively; $P < .006$). Clinical participant outcomes as determined with the PGIC scale did not differ between fluoroscopy-guided and CT-guided injections ($P = .15–.96$).

Conclusion: Radiation exposure in fluoroscopy-guided lumbar spinal injections was lower for participants and higher for physicians when compared with CT-guided injections; however, no associations were observed between clinical participant outcomes and type of imaging-guided injection technique at all evaluated time points.

Many patients with radicular pain due to nerve root compression or low back pain related to degeneration of the facet joint respond favorably to imaging-guided spinal therapeutic injections with steroids (1–3). Lumbar transforaminal epidural and lumbar facet joint steroid injections can be performed reliably, safely, and quickly with either a fluoroscopy-guided or CT-guided technique (4–6).

However, it is unknown how the amount of radiation dose exposure differs between patients and the physicians performing the procedures, if at all. Moreover, it has not been specifically studied whether fluoroscopy-guided injections yield more favorable clinical patient outcomes than CT-guided lumbar spinal therapeutic injections or vice versa. Thus, we hypothesized that the radiation exposure for patients and interventional physicians is different between these two techniques. Our second hypothesis was that patient clinical outcomes after imaging-guided lumbar spinal therapeutic injections with long-acting steroids may be influenced by the chosen imaging-guided technique.

Thus, the aims of our observational study were to compare *(a)* the procedure-related radiation exposure for participants and interventionalists and *(b)* the clinical outcomes of participants with fluoroscopy-guided and CT-guided lumbar spinal injections.

Materials and Methods

Participants

Institutional review board approval was obtained for this single-institution prospective observational study (EK-12/2009, EK-22/2009). Written informed consent and permission to use the participants' data for scientific purposes were obtained before the intervention. Participants were informed about the procedure and the associated risks and benefits of the lumbar spinal injections.

Between October 2009 and April 2016, 1446 participants received transforaminal epidural injections or facet joint injections under fluoroscopic or CT guidance

Abbreviation

PGIC = Patient Global Impression of Change

Summary

Radiation exposure in fluoroscopy-guided lumbar spinal injections is lower for patients and higher for physicians when compared with CT-guided injections; however, no associations were observed between patient outcomes and type of imaging-guided injection.

Implications for Patient Care

- The mean effective radiation dose for patients is lower for fluoroscopy-guided compared with CT-guided lumbar spinal injections.
- The mean radiation exposure for interventionalists is higher during fluoroscopy-guided compared with CT-guided lumbar transforaminal epidural and lumbar facet joint injections.
- The imaging-guided injection technique, whether fluoroscopy- or CT-guided, did not have an impact on patient outcomes.

(Figs 1–3). The mean participant age was 60.6 years (range, 18–91 years). The mean age of women was 62.5 years (range, 18–91 years), and the mean age of men was 58.3 years (range, 18–90 years).

Participant and physician radiation exposures were measured during fluoroscopy-guided and CT-guided lumbar transforaminal epidural injections and lumbar facet joint steroid injections in 199 participants (fluoroscopy-guided lumbar transforaminal epidural injections: n = 55; CT-guided lumbar transforaminal epidural injections: n = 70; fluoroscopy-guided lumbar facet joint injections: n = 24; CT-guided lumbar facet joint injections: n = 50).

Participants' outcomes after therapeutic fluoroscopy-guided and CT-guided lumbar transforaminal epidural and lumbar facet joint steroid injections were obtained in 1247 participants (fluoroscopy-guided lumbar transforaminal epidural injections: n = 449; CT-guided lumbar transforaminal epidural injections: n = 199; fluoroscopy-guided lumbar facet joint injections: n = 390; CT-guided lumbar facet joint injections: n = 209).

The medical history and physical examination for each participant was performed by orthopedic surgeons and rheumatologists. The imaging-guided lumbar spinal injection procedures were indicated and requested by orthopedic surgeons and rheumatologists on the basis of the participant's medical history, symptoms, and clinical and medical imaging findings. Lumbar transforaminal epidural injections were indicated in patients with radicular pain due to nerve root compression without motor deficits (7). Lumbar facet joint steroid injections were indicated in patients with nonradicular low back pain due to osteoarthritis of the lumbar facet joints (7).

Our study inclusion criteria were participant referral to a single-center academic radiology department for a single lumbar segment steroid injection procedure including the L5-S1 facet joint and participant inclusion in the outcomes database for imaging-guided therapeutic musculoskeletal injections of the University Hospital Balgrist. As part of a convenience series, each patient undergoing an imaging-guided lumbar spinal injection since October 2009 was invited as a participant in the outcomes database of the University Hospital Balgrist (8).

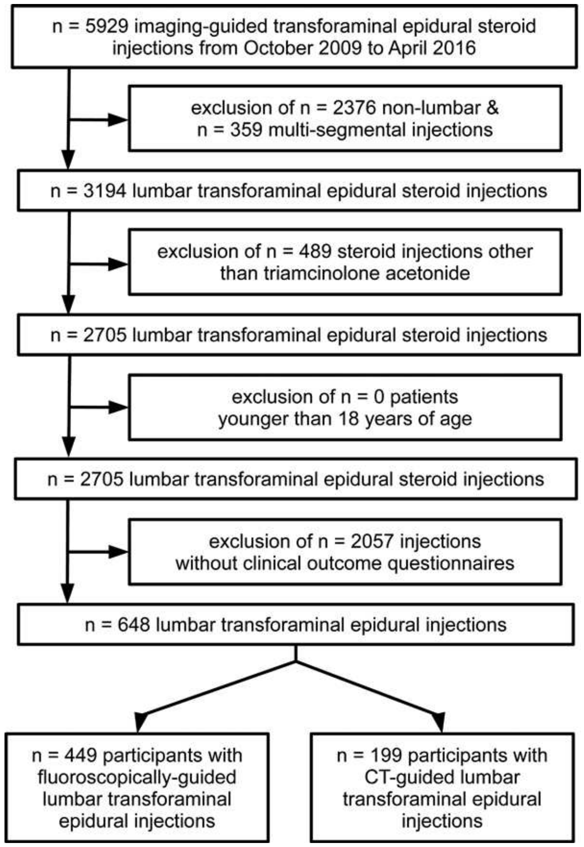


Figure 1: Flowchart of participant inclusion for transforaminal epidural steroid injections. A total of 5929 participants underwent imaging-guided transforaminal epidural steroid injections between October 2009 and April 2016. Of those 5929 participants, 2376 were excluded because they received nonlumbar transforaminal epidural steroid injections, 359 because they received multisegmental injections, and 489 because they received steroid injections other than triamcinolone acetonide. A total of 648 participants underwent lumbar transforaminal epidural injections and returned clinical outcomes questionnaires.

Patients were excluded if they were at a greater risk of bleeding according to published considerations for the management of anticoagulation medication in interventional musculoskeletal radiology procedures (9). Moreover, we excluded postsurgical patients with metallic implants of the spine, patients referred for lumbar spinal injections of two or more segments, patients referred for injection to sites other than the lumbar spine, pregnant patients, and patients younger than 18 years.

Participant assignment to either fluoroscopy-guided or CT-guided lumbar spine injection was predominantly dependent on the point in time: Until August 2014, almost every participant referred for lumbar spinal injection was assigned to undergo a fluoroscopy-guided injection procedure. A second CT scanner with the possibility of a low tube current of 8 mAs was newly installed during the summer of 2014 at our institution due to a capacity shortage in both fluoroscopy-guided and CT-guided interventional musculoskeletal procedures. Starting from August 2014, most lumbar spinal injections were performed as CT-guided

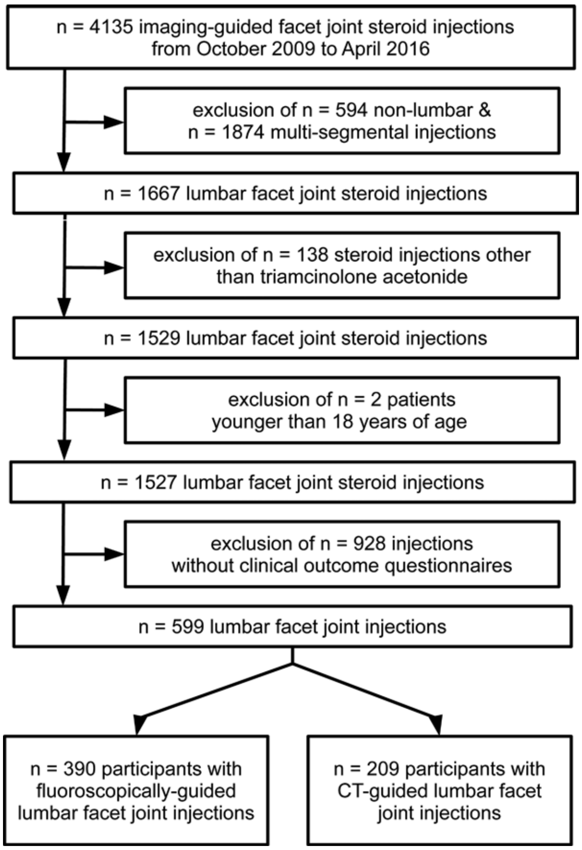


Figure 2: Flowchart of participant inclusion for facet joint steroid injections. A total of 4135 participants underwent imaging-guided facet joint steroid injections between October 2009 and April 2016. Of those 4135 participants, 594 were excluded because they received nonlumbar facet joint steroid injections, 1874 because they received multisegmental injections, 138 because they received steroid injections other than triamcinolone acetonide, and two because they were younger than 18 years. A total of 599 participants underwent lumbar facet joint steroid injections and returned clinical outcomes questionnaires.

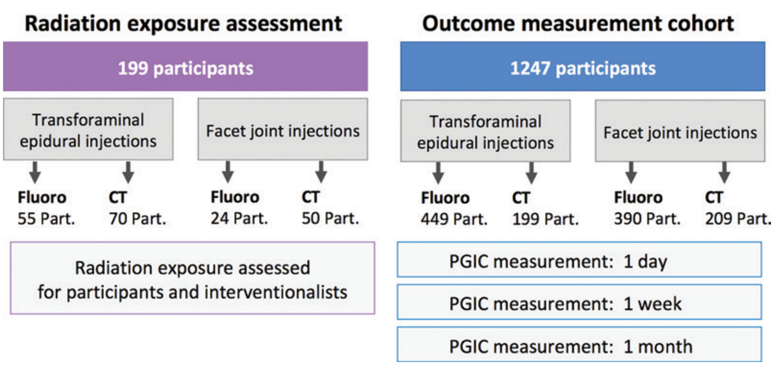


Figure 3: Flowchart shows two cohorts of participants (*Part.*) receiving transforaminal epidural injections or facet joint injections under fluoroscopic or CT guidance. In one cohort, radiation exposure was assessed for participants and interventionalists. In the other cohort, outcome measurements were assessed by using the Patient Global Impression of Change (*PGIC*) scale.

injections with use of the new CT scanner. However, some participants and referring physicians still preferred fluoroscopy-guided lumbar spinal injections.

Fluoroscopy Protocol

All fluoroscopy-guided therapeutic injections were performed with a digital fluoroscopy system with a 43 × 43-cm flat-panel detector (Ultimax-i Modell Drex-U180; Toshiba Medical Systems, Otawara, Tochigi, Japan) by using real-time pulsed fluoroscopy at 3.75 images per second with last image hold without digital subtraction technique. Standard preselected exposure parameters were 40 mA for tube current and 80 kVp for the tube voltage; however, these parameters were modulated by the automatic exposure control. The needle tip was guided to the intervertebral foramen by using biplanar anteroposterior-oblique and lateral projections for fluoroscopy-guided transforaminal epidural steroid injection. Lumbar facet joint steroid injections were exclusively performed in the anteroposterior x-ray beam projection.

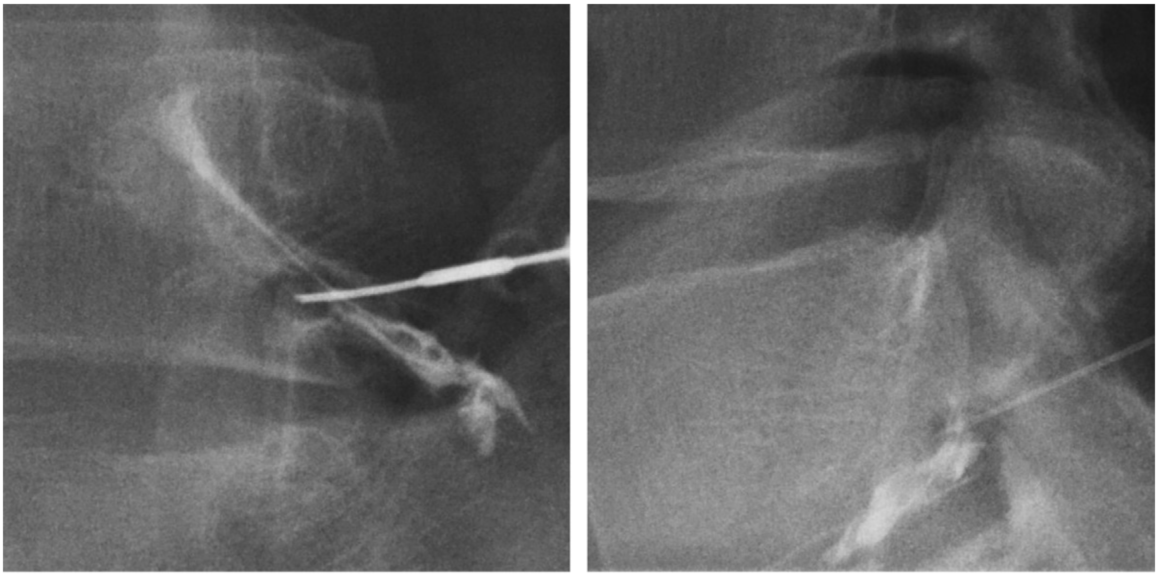
CT Protocol

All CT-guided spinal injections were performed with one 64-channel multidetector CT scanner (Somatom Definition AS; Siemens Healthineers, Erlangen, Germany). A monoplanar CT scout view was obtained in the lateral projection (tube current: 60 mAs, peak voltage: 120 kVp), followed by a spiral CT scan (tube current: 50 mAs, peak voltage: 100 kVp), as preparation for the injection. The preinjection CT images were limited to the lumbar spine segments of interest to minimize the radiation exposure. The needle puncture site on the skin was selected on the sections of the initial spiral CT scan.

Sequential mode CT images with a section thickness of 2.4 mm (i-sequence, tube current: 8 mAs, peak voltage: 120 kVp) were used for tracking the injection needle path during the procedure and for the final scan to document the iodinated contrast agent distribution (10).

Injection Procedures

One of eight fellowship-trained musculoskeletal radiologists from the University Hospital Balgrist performed fluoroscopy-guided and CT-guided transforaminal epidural and lumbar facet joint steroid injections (T.J.D., S.B., R.S., C.W.A.P., with 7, 3, 7, and 18 years of experience, respectively, with dedicated musculoskeletal radiology and four additional radiologists with 4–9 years of experience with dedicated musculoskeletal radiology). Each radiologist performed all types of procedures, without individual preferences for fluoroscopy-guided or CT-guided injections. Participants were positioned in the prone position. Injection needles with a diameter of 20 gauge and a length of 7 cm and a diameter of 22 gauge and lengths of 11 or 15 cm were used for application of the drugs. An 18-gauge-diameter, 4-cm-long coaxial introducer needle reinforced the 22-gauge injection needles. An infraneural approach or supraneural, so-called safe triangle, approach with the needle tip adjacent to the intervertebral foramen was used for transforaminal epidural steroid injections (6,11) (Figs 4, 5). A direct dorsal approach was used for lumbar facet joint steroid injections. Fluoroscopic images in the fluoroscopy-guided group



a. b.

Figure 4: Images in 50-year-old man with radicular pain who underwent fluoroscopy-guided lumbar transforaminal epidural injection. Postinjection **(a)** anteroposterior oblique and **(b)** lateral views demonstrate typical contrast agent distribution along left L5 lumbar nerve root.

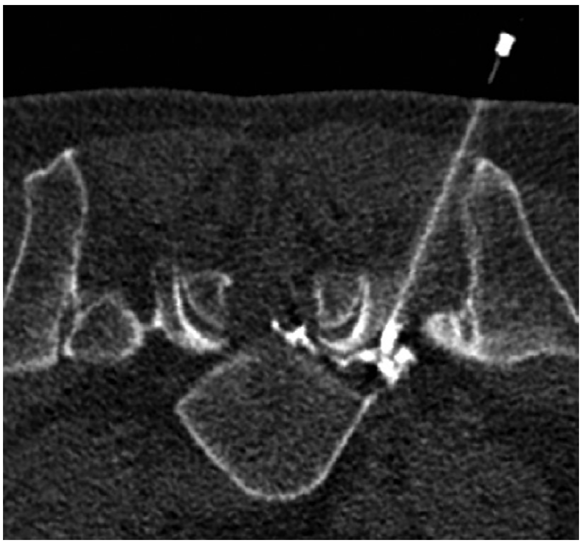


Figure 5: Image in 64-year-old man with radicular pain who underwent CT-guided lumbar transforaminal epidural injection. Postinjection transverse CT image shows typical contrast agent distribution along right L5 lumbar nerve root.

and CT images in the CT-guided group were obtained after iodinated contrast agent injection (iopamidol, 200 mg/mL) to confirm the correct needle tip location. Contrast agent drainage on these fluoroscopic or postinjection CT images was indicative of an intravascular position; as a consequence, the needle tip location was corrected. Subsequently, a lumbar transforaminal epidural injection or facet joint injection was performed with use of local anesthetics (1 mL ropivacaine 0.2% [Naropin; AstraZeneca, Södertälje, Sweden]) and long-acting corticosteroids (40 mg triamcinolone acetonide [Triamcort; Helvepharm, Frauenfeld, Switzerland]). Interventionalists were asked to respect the "as low as reasonably achievable," or ALARA, concept to keep the radiation exposure as low as achievable for both participants and interventionalists. The technologist was not inside the fluoroscopy or CT rooms while fluoroscopic images or spiral CT scans were obtained. The size of the fluoroscopic image was restricted to the smallest reasonable area. Magnification views were obtained at the discretion of each interventionalist. To minimize radiation exposure, the interventionalist did not position his or her wrists or fingers within the x-ray beam during image acquisition.

A plastic forceps served as an extension for the hand and fingers of the interventionalist during needle guidance so that the hand and fingers were not in the path of the x-rays. If technically feasible, the interventionalist briefly left the fluoroscopy room for some of the image acquisitions and went to the control room to observe the ALARA principle (Fig 6). For CT procedures, the interventionalist's preferable position was at the side of the gantry for most of the image acquisitions because it is known that radiation exposure tends to be below a measurable threshold at this particular location within the CT room itself (12,13) (Fig 6). The interventionalist stayed within the CT room during the injection procedure, including the acquisition of the CT images, to track the injection needle path. The interventionalist was in the CT control room during acquisition of the CT scout view and spiral CT scan used to prepare for the injection. An x-ray radiation-shielding screen was not available in either the fluoroscopy room or the CT room.

Conversion Factor

The effective dose (in millisieverts) was established by using conversion factors from International Commission on Radiological Protection publication 103 recommendations (14). The effective dose for fluoroscopy-guided procedures was estimated by multiplying the conversion factor of 0.23 $mSv \cdot Gy^{-1} \cdot cm^{-2}$ by the dose-area product (in $Gy \cdot cm^2$) displayed

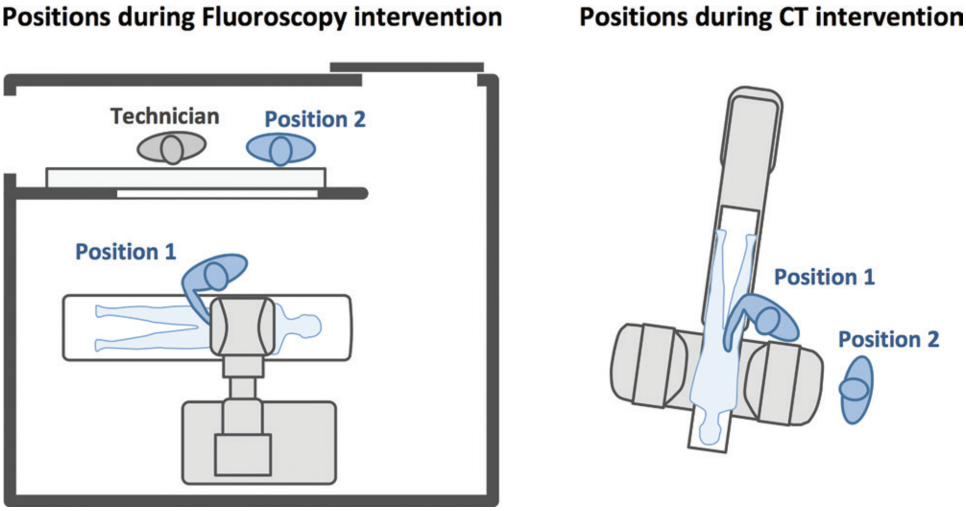


Figure 6: Illustration of imaging-guided injection techniques. Interventionalists stayed within fluoroscopy room (*Position 1*) or CT room (*Position 1*, *Position 2*) during injection procedures to track injection needle path. If technically feasible, interventionalists briefly left fluoroscopy room (*Position 2*) during fluoroscopy and went to control room to observe the "as low as reasonably achievable," or ALARA, principle. For CT procedures, interventionalists' preferable position was at the side of the gantry (*Position 2*) for most of the image acquisitions because radiation exposure tends to be below a measurable threshold at this location. CT technologists were not inside fluoroscopy or CT rooms during imaging-guided injections.

on the control panel of the fluoroscopy system (15). The effective dose for CT-guided injections was calculated by multiplying the dose-length product (in mGy · cm) provided by the patient protocol of the CT scanner by the conversion factor of 0.0127 $mSv \cdot mGy^{-1} \cdot cm^{-1}$ (16).

Dosimeters

Two independent active personal dosimeters composed of a silicon-based detector (DoseGUARD S 10; NUVIA Instruments, Dülmen, Germany) were used to monitor the radiation exposure to the interventionalist during the full duration of the procedure (17). The dosimeters fulfilled the requirements of the Physical Technical Federal Agency (Braunschweig, Germany). One dosimeter measured the radiation dose of the body and was fixed outside the lead gown at the level of the left breast. The second dosimeter measured the radiation exposure of the dominant hand and was worn like a wristwatch. The personal dosimeters were set to zero before each procedure and automatically displayed the measured radiation dose value in microsieverts (17). The measured radiation dose was noted in a database after each procedure.

Participant Outcomes Questionnaires

The Patient Global Impression of Change (PGIC) scale served as a reliable and validated participant outcomes assessment tool at 1 day, 1 week, and 1 month after the therapeutic lumbar transforaminal epidural injections and facet joint injections under fluoroscopic or CT guidance (18,19). The seven-item PGIC scale was used to measure the participant's quality of life outcome after the injection. Participants were asked the following question: "Since your injection, how would you describe the change in activity limitations, symptoms, emotions, and overall quality of life related to your painful condition?" The seven available answers were *(a)* "much worse," *(b)* "worse," *(c)* "slightly worse," *(d)* "no change," *(e)* "slightly better," *(f)* "better," and *(g)* "much better." Only the responses "better" and "much better" were considered as indicative of relevant improvement. Conversely, the responses "much worse," "worse," and "slightly worse" were considered indicative of relevant worsening. The responses "no change" and "slightly better" were interpreted as indicating no change (18,19). Participants were instructed to evaluate specifically the response to treatment (injection procedure) for their major complaints of lower back pain or radicular pain.

Fifteen minutes after the lumbar spinal injection, the seven-option PGIC scale was explained to the participants. The participants were given 1-day, 1-week, and 1-month outcome questionnaires along with a pre-addressed, stamped envelope. Participants were requested to return the completed questionnaires after the 1-month outcome time period.

Statistical Analysis

The unpaired Student t test was used to statistically compare the radiation exposure parameters related to fluoroscopy-guided and CT-guided injection. The PGIC scale data were dichotomized into improved (yes or no) and worsened (yes or no). The percentage of participants who reported improvement was compared with the proportion of participants who reported no improvement by using the χ^2 test (20). χ^2 analyses were also performed for the parameters worsened and not worsened. $P < .05$ was considered to indicate a statistically significant difference between both groups and was calculated by using a statistical software package (SPSS for Windows, release 21.0; IBM, Armonk, NY).

Results

Participants

Tables 1 and 2 summarize participant demographic characteristics. No significant differences between fluoroscopy-guided and CT-guided study group participants were observed with regard to age, height, weight, body mass index, and sex for both lumbar transforaminal epidural injections and facet joint steroid injections.

Participants' Radiation Dose Exposure

The mean effective dose for participants (Table 1) was significantly lower in the fluoroscopy-guided injection groups compared with the CT-guided injection groups ($P < .003$ and $P < .001$).

Table 1: Radiation Exposure to Participants and Interventionalists from Fluoroscopy-guided and CT-guided Lumbar Transforaminal Epidural and Lumbar Facet Joint Steroid Injections

	Lumbar Transforaminal Epidural Injection			Lumbar Facet Joint Steroid Injection		
Parameter	Fluoroscopy-guided Injection (n = 55)*	CT-guided Injection (n = 70)*	P Value	Fluoroscopy-guided Injection (n = 24)*	CT-guided Injection (n = 50)*	P Value
Participants						
Age (y)	56.4 ± 15.8	61.3 ± 13.6	.06	66.0 ± 11.6	59.8 ± 16.7	.10
Height (cm)	171.1 ± 9.8	167.8 ± 8.9	.05	168.9 ± 8.2	170.1 ± 9.4	.60
Weight (kg)	80.9 ± 14.9	79.0 ± 14.9	.47	80.3 ± 15.8	79.6 ± 17.5	.87
Body mass index (kg/m^2)	27.7 ± 4.6	28.1 ± 5.4	.63	28.0 ± 3.9	27.5 ± 5.7	.71
Radiation exposure: effective dose (mSv)	0.24 ± 0.22	0.33 ± 0.10	<.003†	0.10 ± 0.11	0.33 ± 0.13	<.001†
Interventionalists						
Radiation exposure: body (mSv)	$0.42 \times 10^{-3} \pm 0.99$	$0.11 \times 10^{-3} \pm 0.44$	<.03†	$0.38 \times 10^{-3} \pm 1.1$	$0.08 \times 10^{-3} \pm 0.27$	.08
Radiation exposure: wrist (mSv)	$1.44 \times 10^{-3} \pm 2.69$	$0.14 \times 10^{-3} \pm 0.55$	<.001†	$0.46 \times 10^{-3} \pm 0.93$	$0.06 \times 10^{-3} \pm 0.24$	<.006†

* Numbers are means ± standard deviations.

† Statistically significant.

Table 2: Participant Outcomes after Fluoroscopy-guided and CT-guided Lumbar Transforaminal Epidural and Lumbar Facet Joint Steroid Injections

	Lumbar Transforaminal Epidural Injection			Lumbar Facet Joint Steroid Injections		
Parameter	Fluoroscopy-guided Injection (n = 449)	CT-guided Injection (n = 199)	P Value	Fluoroscopy-guided Injection (n = 390)	CT-guided Injection (n = 209)	P Value
Mean age (y)	61.2 ± 15.1	60.5 ± 14.4	.55	60.3 ± 14.0	60.0 ± 12.8	.77
M:F ratio	233:216	101:98	.66	149:241	88:121	.40
Improved at 1 d	143/446 (32) [28–36]	69/197 (35) [28–42]	.52	133/385 (35) [30–39]	60/207 (29) [23–35]	.20
Improved at 1 wk	174/439 (40) [35–44]	90/195 (46) [39–53]	.15	145/382 (38) [33–43]	79/204 (39) [32–45]	.93
Improved at 1 mo	197/416 (47) [43–52]	91/187 (49) [41–56]	.83	128/373 (34) [29–39]	72/196 (37) [30–43]	.63
Worse at 1 d	47/446 (11) [8–13]	22/197 (11) [7–16]	.92	39/385 (10) [7–13]	25/207 (12) [8–17]	.56
Worse at 1 wk	54/439 (12) [9–15])	23/195 (12) [7–16]	.96	43/382 (11) [8–14]	30/204 (15) [10–20]	.28
Worse at 1 mo	55/416 (13) [10–16]	32/187 (17) [12–23]	.26	66/373 (18) [14–22]	42/196 (21) [16–27]	.33

Note.—Outcomes were based on the Patient Global Impression of Chance (PGIC) scale. Except where indicated, numbers are raw data, with the numerator indicating the number of participants with clinically relevant improvement or relevant worsening according to the PGIC scale and the denominator indicating the number of participants who returned the outcome questionnaire. Numbers in parentheses are the percentage of participants who reported clinically relevant improvement or relevant worsening. Numbers in brackets are the lower and upper limits of 95% confidence intervals.

Interventionalists' Radiation Dose Exposure

The radiation exposure of the body and the wrist for the interventionalist (Table 1) was significantly higher during fluoroscopy-guided compared with CT-guided lumbar transforaminal epidural injections ($P < .03$). Moreover, the radiation exposure of the wrist for the interventionalist was significantly higher during fluoroscopy-guided compared with CT-guided lumbar facet joint steroid injections ($P < .006$). The radiation exposure of the body for the interventionalist was also higher during fluoroscopy-guided compared with CT-guided lumbar facet joint injections; however, the difference was not statistically significant (P = .08).

Participants' Outcomes

Table 2 shows that the proportions of participants who reported improvement and worsening with use of the PGIC scale were similar and did not differ significantly (P = .15–.96) between the fluoroscopy-guided and CT-guided lumbar transforaminal epidural and facet joint steroid injections at any evaluated time point. The proportion of participants reporting clinically relevant improvement 1 month after lumbar transforaminal epidural injection was 47% (197 of 416) with fluoroscopic guidance and 49% (91 of 187) with CT guidance (P = .83). The corresponding proportion of participants reporting clinically relevant improvement 1 month after lumbar facet joint injection was 34% (128 of 373) with fluoroscopic guidance and 37% (72 of 196) with CT guidance (P = .63). The percentage of participants who reported clinically relevant worsening 1 month after lumbar transforaminal epidural injection was 13% (55 of 416) with fluoroscopic guidance and 17% (32 of 187) with CT guidance (P =

.26). The corresponding proportion of participants reporting clinically relevant worsening 1 month after lumbar facet joint injection was 18% (66 of 373) with fluoroscopic guidance and 21% (42 of 196) with CT guidance (P = .33).

Interim Treatments

Eight participants from the fluoroscopy-guided group and one participant from the CT-guided group received interim treatments within the 1-month observation period after lumbar transforaminal epidural injections: All but one of the nine participants underwent lumbar spinal surgery, whereas one participant from the fluoroscopy-guided group underwent lumbar facet joint injections subsequent to the evaluated lumbar transforaminal epidural injection. Notably, these nine participants returned the outcome questionnaires; however, the 1-month PGIC scale was not filled out by any of these nine participants after interim treatments within the 1-month observation period subsequent to lumbar transforaminal epidural injections.

Seven participants in the fluoroscopy-guided group received interim treatments within the 1-month observation period after lumbar facet joint injections: Two participants underwent lumbar spinal surgery and reported relevant worsening on the 1-month PGIC scale, one participant received facet joint injections in the adjacent L5-S1 segment, two participants received repeat lumbar facet joint injections at the same level, one participant underwent lumbar interlaminar epidural steroid injection, and one participant received systemic steroid treatment and reported no change on the 1-month PGIC scale subsequent to fluoroscopy-guided lumbar facet joint injections. Notably, all four participants who underwent repetition of any type of imaging-guided injection therapy returned the outcome questionnaires; however, the 1-month PGIC scale was not filled out by these participants after lumbar facet joint injections. No participant of the CT-guided group received interim treatments within the 1-month observation period after lumbar facet joint injections.

Discussion

In our study, the participant radiation dose exposure was 1.4 times lower for fluoroscopy-guided compared with CT-guided lumbar transforaminal epidural injections and 3.3 times lower for fluoroscopy-guided compared with CT-guided lumbar facet joint steroid injections. Conversely, the radiation exposure to the body and wrist of the interventional physicians was between 3.7 times and 10 times higher for fluoroscopy-guided compared with CT-guided lumbar spine injections. It must be noted that the amount of radiation dose exposure for participants was determined with multiplication of established conversion factors, whereas the amount of radiation dose exposure for interventionalists was measured with two independent active personal dosimeters.

Remarkably, the clinical outcomes of the large study cohort of 1247 participants were similar at all evaluated time points up to 1 month, without statistically significant differences between the fluoroscopy-guided technique and the CT-guided therapeutic lumbar spine steroid injections with local anesthesia and long-acting corticosteroids. In our study, almost half of the 648 participants reported clinical improvement on the PGIC scale 1 month after imaging-guided lumbar transforaminal epidural injections. More than one-third of all 599 participants reported clinical improvement on the PGIC scale 1 month after imaging-guided lumbar facet joint injections.

Maino et al (4), in a retrospective study, found that the patient radiation dose exposure for fluoroscopy-guided lumbar spine injections was approximately eight times lower than that for CT-guided lumbar spine injections. However, a possible study bias arose from the fact that the authors retrospectively compared fluoroscopy-guided lumbar spine injections from their own service against CT-guided lumbar spine injections performed by radiologists at six various institutions across the same country.

A low radiation exposure for participants and interventional physicians according to the ALARA principle as well as a safe approach is mandatory for any imaging-guided procedure. Although clinically guided, US-guided, and MRI-guided lumbar injection therapies with long-acting steroids are described in the literature, most physicians worldwide, including the staff at our institution, feel more confident regarding patient safety with fluoroscopy-guided and CT-guided lumbar spinal injection techniques in a daily clinical routine (6,21–24). Physicians are obliged to reduce the radiation exposure as low as possible. Thus, the applied standard fluoroscopy and CT protocols in our study were adjusted as described earlier according to the ALARA principle. Fluoroscopy-guided lumbar spine injections necessitate real-time manual guidance and manipulation of the needles; thus, the body, wrist, and hand of the interventionalist is exposed to scattered radiation due to the proximity of the primary x-ray beam (25). Conversely, CT-guided lumbar spine injections frequently allow steering and manipulation without simultaneous verification of the needle location by the x-ray beam (12). Thus, the radiation exposure for the body and wrist of the interventionalist was significantly higher during fluoroscopy-guided compared with CT-guided lumbar spinal injections in our study. Another advantage of CT-guided spinal injections is that the interventionalist may leave the CT room and stop in the control room during image acquisition to minimize the radiation exposure (26).

This study had limitations. First, we used an observational study design, with nonrandomized sequential participant assignment to either a fluoroscopy-guided or CT-guided lumbar spine injection procedure predominantly dependent on the injection date. In addition, an indirect technique (dose-area product and dose-length product measurements) was used to estimate effective radiation dose in participants instead of direct radiation exposure quantification techniques with dosimeters. However, the use of participant dosimeters to estimate the effective radiation dose was determined to be impractical in our study. The effective dose concept was developed to estimate radiation side effects for the uniform equivalent dose to the whole body on the basis of a population of all ages and both sexes. Several uncertainties were expressed in the calculation and appliance of effective doses related to fluoroscopic procedures and CT for individual patients (27). In contrast, we used effective doses for the comparison of the amount of radiation dose exposure. Active personal dosimeters were used in our study. The International Atomic Energy Agency found that the general performance of active personal dosimeters is comparable to that of standard passive dosimetric systems (28). These active personal dosimeters provide a satisfactory energy and angular response and are increasingly used for measurements of occupational exposure in the field of interventional radiology (29). However, active personal dosimeters may underestimate the radiation exposure in pulsed radiation such as pulsed fluoroscopy, which was used in the present study (29). Another limitation is the fact that interim treatments in some participants may have led to a confounding factor. However, such a treatment was rare in this study population within the 1-month observation period and was only seen in 16 of the 1247 participants (1.3%), and only three participants who underwent interim treatment (0.2%) filled out the 1-month PGIC questionnaires. Thus, the resulting confounding factor due to interim treatment was considered minimal. Finally, a lack of statistical significance between the imaging-guided participant groups with regard to clinical outcomes does not prove equivalence (30).

In summary, radiation exposure in fluoroscopy-guided lumbar spinal injections was significantly lower for participants and higher for physicians when compared with CT-guided injections and vice versa; however, no associations were observed between clinical participant outcomes and type of imaging-guided injection technique at all evaluated time points.

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